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SWEET SORGHUM AS A SOURCE OF SUGAR

Since their introduction in the 1850's, the sweet sorghums have periodically attracted the interest of farmers and sugar producers in the United States because of the sucrose content of their stalks. Except for their seed heads, the tall slender stalks resemble sugarcanes, and their adaptability to the various climatic conditions and soils of the United States has suggested that they could be cultivated extensively as a sugar crop.

Farmers were able to produce syrups from the sugar-bearing juices of their stalks, but all commercial efforts to produce crystalline sugar from these juices proved uneconomic. Many of the difficulties encountered in the early efforts to produce crystalline sugar can be attributed to the lack of suitable disease-resistant, high-sucrose varieties, while other problems arose in the factories which attempted to process the sweet sorghum juices under the same conditions used for recovering sugar from sugarcanes and sugar beets.

Unlike sugarcane or beet juices, the sweet sorghum juices contained large quantities of starch, and the high processing temperatures employed in the factories pasted the starch, and so thickened the process syrups that efforts to crystallize sugar ranged from unsatisfactory to impossible. The sweet sorghum juices also contained another impurity, aconitic acid, which interfered with sugar recovery, and for which no technology for elimination existed until the 1940's.

The field characteristics of the sweet sorghums make them very attractive in areas where water supplies are limited, or where their ability to produce a crop in approximately 100 days is desirable. They are also interesting because of their low labor requirements. Coordinated into a sugar production scheme with either sugarcane or sugar beets, they have a potential for supplementing the sugar output of existing factories, since they are harvested in the summer or fall when the factory is idle. From the standpoint of economic feasibility, it is doubtful that the sweet sorghums as the sole source of sugar production can provide a sufficiently long harvest season to justify construction of a sugar factory.

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The Agricultural Research Service's Food Crops Laboratory, USDA, initiated research on the sweet sorghums in 1964 at Weslaco, Tex., as a part of a cooperative effort with Texas A&M University's Lower Rio Grande Valley Research and Extension Center, and the U. S. Sugar Crops Field Station, ARS, at Meridian, Miss., to evaluate newer sweet sorghum varieties with promise for commercial sugar production, to study crop management practices, and to explore practical methods for recovery of crystalline sugar from the plant juices.

The Food Crops Laboratory has assisted in the examination of newly-developed breeding lines of sweet sorghums, in studies of the plant requirements for fertilizers and water, in determination of optimal times for planting, and in evaluating other field practices, by milling the stalks and analyzing the extracted juices. From the analytical data provided, it has been possible for the geneticists to evaluate varieties as potential sources of commercial sugar production, and for agronomists to select the field practices which would provide maximum yields of sugar. Three new varieties have been selected and released: Rio, Roma, and Ramada--all considered suitable for commercial sugar production. Much valuable information has been collected also regarding the field practices which will assure maximum production of sugar.

Analyses of the juices from sweet sorghum stalks planted in many different areas, at various times of the year, and under differing field conditions, have provided information regarding the upper and lower limits of sugar production by the plant, as well as the identity and quantity of objectionable impurities present, such as starch and aconitic acid, which a factory must efficiently remove before economic quantities of crystalline sugar can be recovered from the crop. These studies were followed by an extensive program of laboratory testing of methods for treating the juices to eliminate these objectionable impurities without destroying the sugars. Because of the resemblance of the sweet sorghum stalks to sugarcanes, primary consideration was given to treating the juices by processes which could be fitted into sugarcane factory operations without expensive modification of existing equipment.

It was found that the extraction of the sugar-bearing juices from the sweet sorghum stalks could be achieved in a manner similar to that used for sugarcane by crushing the stalks repeatedly under considerable pressure and adding some water to help in washing the sugar from the crushed stalks. The seed heads and most of the leaves must be removed before crushing to avoid extracting undesirable non-sugars from these materials.

Tests showed that the addition of milk of lime to the juices to produce a pH range of 7.7-7.9, heating to approximately 130^{o}F., then adding a small quantity of a flocculating agent and settling the juice, would effectively trap and settle out over 95 percent of the starch and much of the other suspended matter. Except for the pH range and the low temperature employed with the sorghum juices, this operation was essentially the same as sugarcane juice clarification.

The evaporation of water from the settled or clarified juices to form a syrup was done under vacuum at a temperature of approximately 140°F. in a manner similar to that employed by the sugarcane industry. When a thin syrup had been obtained with a solid content of about 35 percent, it was drawn from the evaporator and retreated much as with the raw juice earlier, to settle out an additional quantity of starch and other undesirable materials.

Following this clarification treatment, the thin syrup was again taken into the evaporator and sufficient additional water removed under vacuum to produce a thick syrup of some 65 percent solids. A treatment of the thick syrup to remove aconitic acid was necessary at this point in processing. This treatment required adding milk of lime and calcium chloride, heating the syrup to boiling, and settling out the insoluble calcium salt of aconitic acid. This operation was not necessary in sugarcane processing because the canes contain only a fraction of the aconitic acid found in the sweet sorghums. When the insoluble aconitate had been removed, the clear syrup was ready for crystallization of its sugar content in conventional sugar factory equipment.

These various operations were tested in the laboratory using several gallons of juice per test. The range of temperatures, pH's, and densities were determined which would allow removal of the greatest quantities of objectional impurities without affecting the sugar content of the juices and syrups. A pilot plant was designed to permit evaluation of these selected operations on a scale and in a manner which approximated factory conditions.

The pilot plant, when ready for use in the summer of 1970, was in reality of small sugar factory, capable of processing some 400 gallons of raw sweet sorghum juice to raw sugar and molasses. Tests made in the pilot plant during the summers of 1970-1973 with sweet sorghum juices verified the results of laboratory-scale tests, and indicated that the various operating conditions selected in the course of these small-scale tests were equally effective in processing much larger quantities of materials.

The raw sugars produced from pilot plant operations compared favorably with raw cane sugars in all respects except that they contained somewhat more mineral matter. As this mineral content derived principally from the soils in which the sweet sorghums were grown, such a problem is expected to decrease after repeated planting of this crop on the same soils.

Extensive pilot plant studies and laboratory and field research on the sweet sorghums are not yet complete; more data are needed to assure the establishment of an economic sugar industry. Several additional varieties of sweet sorghum are needed to meet all requirements of soils and climates. Harvesting and leaf removal systems will need study, and all pilot plant operations must be developed into a balanced, continuous process to conform to factory practice. However, some of the most formidable problems which handicapped prior efforts to develop the sweet sorghums as a commercial source of sugar have been resolved, and the crop has indicated real promise for improving the United States' position of independence from imported sugar to supply its demands for this essential foodstuff.